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USDA/DFIM R&D Program — PROGRESS REPORT IV

1. Title: IMPACT OF CHEMICAL CONTROL APPLICATIONS IN THE FOREST ON BENEFICIAL INSECTS

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POLLINATING INSECTS

INTRODUCTION

The importance of pollinating insects to the efficient reproduction and vigor of many plants is well known, as is the status of the Apoidea (bees) as the most effective group among the pollinators. Extensive reviews of the part bees play in the pollination of crop plants are supplied by Free (1970) and McGregor (1976). By comparison, there has been very little research into the dependence of non-cultivated plants, and especially montane plants, upon insect pollination. Macior (1974) found 27 of 29 Rocky Mountain species studied to be dependent upon insects for fruit production. McGregor (1976) lists 45 genera, plus 2 families containing "numerous" or "several" genera, of wild flowers and ornamentals which the literature indicates are reliant upon insect pollination.

All in all, the beneficial aspects of wild forbs, shrubs and trees are difficult to assess and probably impossible to evaluate monetarily. Bohart (1952) supposed the most drastic effect of the elimination of pollinators would be in uncultivated areas, where soil-holding and soil-enriching plants would die off. He also pointed out the aesthetic value of blooming wildflowers. The production of seeds, fruits and nuts for wildlife consumption is also important. Knott (1950) stated that 5 plant families--the Amaranthaceae, Gramineae, Leguminosae, Polygoniaceae and Rosaceae—provide the bulk of the diets of quail and pheasants. The latter 3 of these families are entomophilous (McGregor, 1976). According to Knott, squirrels, bears and raccoons derive a sizable percentage of their diets from a number of forest plants which Manning (1943) and Yeager

(1937) state are dependent upon, or benefitted by, insect pollination. Martin et al. (1951) provide a general reference to the feeding habits of wildlife.

Yet another role of flowering plants is to maintain the integrity of an area's pollination ecology. A particular species of plant provides nectar and pollen which is needed by the insect pollinator; the insect then serves as a pollinating agent not only for that species, but for many others as well. Thus seemingly unimportant wild flowers may contribute to the welfare of a group of bees needed to pollinate a plant which is of direct importance to man, wildlife or the ecosystem.

In view of the importance of pollinators to a forest, it is essential to have information on the impact of chemical insecticides upon them. In 1976, forest plots in northeastern Oregon were treated in order to obtain data on the effects of bees, other non-target insects and other animals.

Beginning in 1946, DDT was used on several occasions to control rather irregular outbreaks of the Douglas-fir tussock moth, Orgyia pseudotsugata McD. However, due to increased awareness of possible detrimental environmental effects of this pesticide, DDT was banned by the Environmental Protection Agency in 1972 for nearly all uses. Permission was granted in 1974 for one final application of DDT to 460,000 acres in the Pacific Northwest.

The United States Department of Agriculture, Douglas-fir Tussock Moth Research and Development Program was organized in 1975 to investigate many aspects of the Douglas-fir tussock moth problem, including the necessity of finding a suitable control material to replace DDT. Three candidate insecticides were selected: carbaryl (Sevin-4-oil formulation), acephate (Orthene) and diflubenzuron (Dimilin or TH 6040, a urea compound). Our phase of the project is obtaining environmental impact data to assist in developing cost-benefit ratios to determine possible future use of the materials in tussock moth

campaigns.

Disastrous effects of carbaryl on bees are well documented (e. g., Atkins, 1975; Johansen, 1977). Johansen's (1972b) tests on alfalfa indicated carbaryl 80% WP at 0.1 lb ai/acre was highly toxic to bees even after field weathered for 2 days. There was a typical pattern of susceptibility (Megachile pacifica Panzer Nomia melanderi Cockerell Apis mellifera L. Bombus spp.) in the bees he studied. It has long been known that formulation affects the toxicity of an insecticide to bees (see Johansen, 1969) and that oil solutions are among the least hazardous (Johansen, 1972a; Johansen and Kleinschmidt, 1972). Lagier et al. (1974) found ULV Sevin-4-oil was much less detrimental to honey bee colonies than carbaryl WP, due to shorter residual effects. However, this shorter residual effect only occurs with dosages of 0.5 lb ai/acre or less. Morse (1972), working in Pennsylvania forests, suggested Sevin-4-oil was preferable to other carbaryl formulations, but even the Sevin-4-oil formulation caused losses which would economically affect a commercial apiary. Johansen (1975) obtained high honey bee kills from Sevin-4-oil at 1.0 lb ai/acre on 20-acre forest plots in northern Idaho.

Atkins (1975) groups acephate with carbaryl among the pesticides he calls "highly toxic" to bees, but points out the dosage of acephate very closely affects the severity of its threat to honey bees. Johansen (1977) classifies it as "minimal hazard, if applied during late evening, night, or early morning on blooming crops." Its residual effect on alfalfa leafcutting bees (M. pacifica), alkali bees (N. melanderi) and honey bees is much lower than that of carbaryl (Johansen, 1972b). Johansen's (1975) study on northern Idaho plots showed acephate at 0.5 lb ai/acre produced rather low honey bee kills and residual effects were negligible. These results are in agreement with those observed by Buckner and McLeod (1975).

Even though diflubenzuron is a relatively new experimental compound, it has been investigated fairly thoroughly. Both Atkins et al. (1976) and Johansen

(1976a) found that it was non-hazardous to honey bees at up to 0.5 lb ai/acre in direct exposure studies. Since the material is effective against insect larvae by ingestion, and long-lasting residues have been detected in field studies (Holland, 1975), the potential hazard to bees from pollen contamination was studied by Johansen (1976b). He found that feeding colonies with syrup containing 100 ppm diflubenzuron resulted in one instance of queen supercedure, death of brood, and production of dwarfed workers. Field application on rape seed caused no harm to honey bee brood or adults, and greenhouse studies showed no hazard to alfalfa leafcutting bee adults or progeny from pollen contamination. Honey bees also were unharmed when caged on field-weathered residues (for method, see Johansen, 1972b) applied at up to 0.5 lb ai/acre (Johansen, 1973).

A 3-year study to determine the effects of these 3 insecticides upon pollinating bees and pollination of forest plants was begun in June 1975, and will be concluded in April 1978. Results obtained during the first 2 years are presented here.

STUDY AREAS

Nine plots were selected in the Wallowa-Whitman National Forest in northeastern Oregon (Figs. 1 and 2). Six were in the Union District (eastern side) of the forest, while 3 were in the LaGrande District (western side). All plots were 200 acres in area, centered on streams. The plots allocated for acephate and carbaryl treatment were enlarged by 120 acres for the treatment year. This area was added to the upstream portion of Lower Lick Creek and Jordan Creek plots, and to the downstream portion of Lower Goose Creek and Ladd Creek plots. All plots were chosen as potential Douglas-fir tussock moth habitat, but no control materials had been applied to the plots prior to the study.

R. Clausen of the University of Idaho determined the plant communities in selected subplots, using Hall (1973). His determinations are used in the following descriptions (see Table 1).

Table 1. Key to classification of plant communities (Hall, 1973).

Plant Community	Code
Ponderosa pine - Douglas-fir - elk sedge	CD-G1-11
Ponderosa pine - Douglas-fir - snowberry- oceanspray	CD-S6-11
Mixed conifer - pinegrass, ash soils	CW-G1-12
Lodgepole pine - big huckleberry	CL-S5-11
Lodgepole pine - pinegrass - grouse huckleberry	CL-G2-11
White fir - twinflower - forb	CW-F3-11
White fir - big huckleberry	CW-S2-11
White fir - grouse huckleberry	CW-S8-11
Sub-alpine fir - big huckleberry	CE-S3-11

Ladd Creek (LAC)

LAC is in the LaGrande District, isolated by more than 5 miles from the closest plot, Whiskey Creek. Elevation ranges from ca. 4240 to 4900 ft. Northeastern quarter of the plot is formed by a steep slope, but the rest of the plot rises more gently from the stream bottom. Most of LAC is a CW-S2-11 community,

with lesser elements of CD-S6-11, CW-S8-11, and CW-S2-11. The main bee forage plants occurring in the plot are Symphoricarpos albus and Solidago sp.

Whiskey Creek (WC)

WC is in the LaGrande District, separated from Jordan Creek by ca. 1.3 miles and 2 ridges. Elevation is ca. 4980 to 5600 ft., and the plot is mainly a steep-sided valley. WC is mostly CW-S2-11, with some CL-S5-11, CL-G2-11, and C2-S6-11. Bee forage is provided mainly by Ranunculus, Taraxacum, Senecio triangularis, Mertensia and Phacelia.

Jordan Creek (JC)

JC varies in elevation from ca. 4800 to 5380 ft., and is also a steep-sided valley. Plant communities are mainly CW-S2-11, with smaller amounts of C2-S6-11 and CL-S5-11. Mertensia, Phacelia, Trifolium, Taraxacum, and Mentha are the most common nectar and pollen sources.

Upper Lick Creek (LC1)

Lick Creek is in the Union District. LC1 is separated from LC2 by ca. 0.5 mile. Its elevation ranges from ca. 4840 to 5200 ft. The creek flows through a dry, rocky, gently sloping valley in this area. Tree cover is relatively sparse. Plant communities are CW-G1-12, CD-S6-11 and CW-S2-11. The plot is heavily grazed and forage plants are rather scarce, with Trifolium and Phacelia being the most common.

Lower Lick Creek (LC2)

LC2 ranges in elevation from 4240 to 4750 ft. Sides of the valley are steeper and rockier than at LC1. The major plant community is C2-S6-11; CW-S8-11 and CW-G1-12 occur less commonly. Ground cover has largely been removed by cattle grazing. The more abundant nectar and pollen plants are Symphoricarpos, Phacelia, and Trifolium.

Big Creek (BC)

BC is in the Union District. It is separated from LC2 by ca. one mile and a ridge, and from Velvet Creek plot by ca. 0.7 mile and a ridge. Its elevation ranges from ca. 4120 to 5000 ft. It is a moderately sloping valley composed mainly of C2-S6-11, with small amounts of CW-G1-12. Symphoricarpos is abundant, and Vicia and Trifolium are also common.

Velvet Creek (VC)

Elevation of VC varies from 4680 to 5480 ft. The valley slopes moderately. Its main plant community is CW-S2-11, with lesser amounts of CW-G1-12 and CE-S3-11. Mertensia, Cynoglossum, Mentha, and Symphoricarpos occur in abundance along the creek and provide good bee forage.

Upper Goose Creek (GC1)

Goose Creek is in the Union District. GC1 is separated from GC2 by ca. 0.7 mile. Its elevation varies from ca. 4130 to 4720 ft. The plot is in a broad, flat valley with the western side formed by a fairly steep slope. The soil is quite dry. CW-G1-12 is the major plant community, while CE-S3-11 and CW-S2-11 also occur. Symphoricarpos occurs abundantly but was badly diminished by cattle in the 1976 season. Best bee forage plants are Cynoglossum, Cardaria, Trifolium and Symphoricarpos.

Lower Goose Creek (GC2)

GC2 has an elevation ranging from ca. 4000 to 4400 ft. and is a moderately sloping valley with dry soil. CW-G1-12 is the most common plant community, while CD-S6-11 and CW-S8-11 are also on the plot. Symphoricarpos is the most abundant nectar and pollen plant. Cynoglossum and Trifolium are also quite common.

MATERIALS AND METHODS

Weather Stations

During the 1976 sampling period, weather stations were operating at 3 sites (Figs. 1 and 2), to give a general idea of the weather in the vicinity of the plots. Temperature, relative humidity and rainfall were recorded. The relative humidity data appeared inaccurate and were discarded.

Spray Applications

Treatments began 23 June, 1976. Spray materials were applied with a conventional nozzle and boom system mounted on a Bell 206B Jet Ranger helicopter. No. 8002 Tee-Jet flat fan nozzle tips were used, aiming for a drop size of less than 250 microns VMD. Treatments were applied in 75-foot swaths at 60 mph and 40 psi. Spraying was completed in the early morning of each day. Due to unfavorable weather, distances separating the plots, and number of chemicals to be applied, spraying was not completed until 27 June. Treatments, temperature and wind speed, and dates of application appear in Table 2.

To assess spray deposit, red dye was added to each spray mix, and white Kromekote spray cards and aluminum plates were placed perpendicular to the flight lines, across each plot (cards showed a uniform application in all cases).

To monitor effects of the applications on bees and pollination, several methods were employed. Base line data were gathered in 1975, while impact data were collected in 1976, using virtually the same methods.

Honey Bee Studies

Two colonies of honey bees in standard Langstroth hives were placed near the center of each plot. In 1975 these were recently divided splits (halved colonies), and were quite weak initially. Each colony contained about 3 frames of brood. However, in 1976 overwintered colonies were used, and 17 of the 18 were quite strong initially (about 6 frames of brood). One colony, GC1-A, had

only one frame of brood, but did have a fairly strong field force.

The entrance of each hive was fitted with a Todd dead bee trap (Atkins et al., 1970) and daily death rates were monitored (Fig. 3). Counting of large samples was facilitated by the use of a funnel and 1000 ml graduated cylinder (Fig. 4). The cylinder was calibrated for conversion of volume to number of bees (Anderson et al., 1966). At times during the 1975 season, ants were carrying the trapped dead bees away. Control was achieved by sprinkling small amounts of chlordane around the traps. To avoid the possibility that chlordane was contributing to bee deaths, in 1976 the hives and traps were set on 4"x4" boards which were painted with Stick-um.

Condition of the colonies was determined by noting brood and stores accumulation at intervals through each season. In 1975, this was done by counting the number of frames occupied by brood, pollen or honey. A more accurate assessment was made in 1976 by measuring the comb areas with a grid device divided into square inches (Fig. 5). In addition, LaVerne Boylan, the beekeeper from whom the colonies were rented, made a followup check on colony condition in October 1976 and January 1977.

To obtain pollen samples as well as bees dying within the hives, pollen traps of the type described by Nye (1959) and modified for bee poisoning studies by Johansen (1960), were used with one hive per plot in 1976 (Fig. 6). Pollen samples were sent to R. B. Roberts, Pacific Southwest Forest & Range Experiment Station, Berkeley, CA, for chemical analysis.

Wild Bee Studies

Effects on wild bees were studied by observing their foraging activity on flowering plants. Each observation was composed of 25 "sight units," each unit being one square yard of bloom. All 25 units were on the same plant species. The observer's eye was first trained to visualize a square yard using the

device of Smith and Townsend (1952), and subsequently the area was estimated without the device. Observation of each unit lasted approximately 10 seconds. Sightings were always conducted on warm (>18 C) sunny days between 1100 and 1500 hrs. Observations were made approximately weekly, except in the weeks closely preceeding and following pesticide application, when they were made every one or 2 days.

In most cases, identification of bees at least to the generic level was possible by this method. Occasionally, and especially in the first year of the study, bees were collected with a sweep net for laboratory identification. This was avoided whenever possible, in order to minimize disturbance of the populations. Bumble bees were identified to species, using the key of Stephen (1957). Stephen et al. (1969) was used in identifying all other bees to the generic level. Determinations were checked by comparing them with specimens in the M. T. James Entomological Collection, Washington State University.

Malaise Trapping

Malaise-type traps were operated by E. J. Davis III, under the guidance of W. J. Turner, both of the Department of Entomology, Washington State University. These were placed in the same locations in both seasons, and provided a means of tabulating the taxonomic groups of Apoidea occurring in the plots.

Nesting Studies

Attempts to trap-nest bees of the family Megachilidae proved unfruitful. In 1975, 2 grooved-board blocks containing 200 ¼-inch diameter tunnels (Eves and Johansen, 1974) were placed on dead tree trunks in each plot at the edge of forest meadows. No nesting occurred. In 1976, 5 trap nests of a different design were placed in each plot. These were developed by E. C. Klostermeyer, Department of Entomology, Washington State University, and consisted of thin-

walled cardboard tubes of varying diameter embedded in a vermiculite -paint mixture in half-gallon milk cartons. They were placed closer to creeks than in 1975, so that mason bees would have a ready source of mud for cell construction. In addition, 15 Osmia lignaria Say cocoons containing winter adults were placed in one nest block in each plot.

Some time was also devoted during the 2 summers to searching for bumble bee nests, which were excavated at each season's end. The number of cells and workers were tabulated to provide additional data. Unfortunately, only 4 nests were found on the plots in the 2 seasons' study.

Flowering Plant Studies

Another aspect of the study concerned determining the extent to which some of the more abundant forest flora depend upon insects for pollination. Prior to bloom, plants were enclosed in cages made of galvanized window screen, 18 x 14 mesh (Fig. 7). The cages were firmly secured to 3' wooden stakes. Soil was mounded against the base of each cage to eliminate openings. After flowering, comparable numbers of enclosed and open-pollinated plants in the immediate vicinity were examined for fruit production. Several fruits from each sample were opened, to ascertain whether they bore a normal number of seeds. Failure to produce seeds under the cages indicated a lack of self-pollination in the absence of insects (or other animals) too large to penetrate the screen. Normal fruiting under cages indicated successful self-pollination or pollination by insects such as thysanopterans, which are small enough to pass through the openings in the screen.

When a screened plant set fruit with some success, its seeds were collected, along with seeds from nearby open-pollinated plants. Germination trials were conducted, to test the vigor of seeds produced by self-pollination. These tests were run according to the standards and recommendations of the Association

of Official Seed Analysts (1970) and Maguire and Overland (1972).

To determine how the microenvironment of a plant enclosed in screen might be altered , temperature and relative humidity were measured inside several of the cages, and compared to readings obtained amongst neighboring unenclosed plants of the same species. This was done by lifting the screen at one corner and thrusting a Bendix hand-aspirated psychrometer, model HA-2A, into the cage.

The number of fruits produced by plants in spray plots as compared to check plots was also studied. Plants blooming during and shortly after the applications were selected, since they would be most seriously affected by a decrease in pollinators. In late June, plants of only 2 species , Cynoglossum officinale and Mertensia paniculata, could be found in the late bud stage which would be blooming immediately after the sprays. Representatives of these species were marked with tagged stakes and examined after flowering had ceased. A later-blooming plant, Symphoricarpos albus, was also examined in this manner. In doing these comparisons, an attempt was made to select spray and control plots that were as similar climatically as possible, to keep the influence of weather to a minimum.

RESULTS AND DISCUSSION

Honey Bee Studies

Pertinent results of the dead bee trapping appear in Table 3, and in graph form in Figs. 8-12. Table 4 shows the brood measurements for 1975 and 1976, and the beekeeper's assessments of colony condition some months after treatment.

Treatment with carbaryl resulted in very high numbers of dead bees trapped for about 10 days at both LC2 and GC2, and unusually high counts at the nearby check plots, LC1 and GC1. Typical symptoms of carbamate poisoning were observed

for more than a week after application. Huge numbers were dying at the hive. Many "crawlers" or stupified bees were seen around the colony entrances, especially at the treated plots, but also at the check plots. Bees were unusually aggressive at GC1 and LC1 for several days after treatment; at the treated plots they were obviously too impaired to show aggression.

Evaluation of colony condition 10 and 11 days post-treatment revealed the extent of damage to the colonies. Colony A at LC2 showed a solid pattern of capped brood and was obviously a very strong colony before spray. However, all the brood was capped, revealing that the brood cycle was broken within 1-2 days after the application. Examination of LC2-B revealed only a few uncapped larvae and no eggs. The larvae appeared dull and flattened. Here again, the brood cycle was strongly disrupted soon after treatment. Both colonies at GC2 fared slightly better. Although few adults were in evidence at the first colony check, brood of all ages was present, albeit in very erratic patterns. Except for GC1-A, the check colonies at GC1 and LC1 were reasonably healthy at this first inspection. All contained a high proportion of young brood and eggs. GC1-A was very weak from the start, and carbaryl contamination from GC2 may have caused the queen (which was observed) to cease laying for a time.

At summer's end, 45-47 days post-spray, colonies on the check plots near the carbaryl-treated plots were in good condition, and these colonies (GC1 and LC1) were still healthy 7 months after spray. At LC2 both colonies were dead as of the final inspection of the summer. Ants had invaded the hives, and mold was growing on the combs. GC2 colonies managed a slight recovery, but colony A starved by January and colony B was weak.

Acephate at both one and 2 lb ai/acre was much more detrimental to honey bees than would be predicted by a review of previous investigations. Moderate to high kills occurred for about 2 weeks at both dosages, probably due at least in part to the cool weather in the LaGrande District 2-3 days after spray (Fig. 13).

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This would reduce foraging immediately after spray, causing more deaths when warm weather came and field bees were being exposed to the chemical. Low temperatures also increased the residual toxicity of the material (Johansen, 1976a).

However, injury to the colonies was more severe than the trap counts indicated. Obviously, a greater proportion of the foraging bees were killed in the field by faster-acting acephate than by carbaryl. Strength of the colonies at LAC and JC was greatly reduced. Ten days after treatment there was no obvious activity at any of the 4 hives, despite 21 C temperature and direct sunlight striking the colonies. None of the four colonies were effectively removing dead bees from the hive entrances or bottom boards. Typical symptoms of organophosphorous poisoning were prevalent. Remaining bees were spinning or moving erratically up to 2 weeks after application. Large numbers of bees, wet with regurgitation were seen dying at all 4 acephate-treated colonies. At both plots, as well as at the neighboring check plot, WC, bees were quite aggressive, stinging without provocation.

Inspection of the acephate-treated colonies 11-12 days after spray showed that brood cycles had been quickly broken in all 4 of the hives. All brood was old and capped, and no pollen was being brought into any of the colonies. At LAC-B laying workers were indicated by the presence of several eggs in many of the cells. At WC colony A was healthy, but colony B had only capped brood. By season's end, one colony at LAC was dead and the other contained only a small amount of laying worker brood. The same situation was found at JC. WC-B (a check) had no brood at all. By January, all colonies that had been on acephate-treated plots were dead, as was WC-B.

Diflubenzuron had no detectable effect on either adult mortality or brood rearing. Todd trap counts remained normal and all colonies at VC and BC were healthy at 10-day and 46-day inspections. It is odd that BC-B was found "below average" by the beekeeper in October, and dead in January. The timing

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of the colony's demise is such that the queen may have been injured or lost during the final colony check of the summer. In any case, it is very unlikely that diflubenzuron contributed to the death of a colony which had flourished all summer.

Findings of the honey bee poisoning aspects of this study thus coincide closely with other researchers' results, except in the case of acephate. Immediate disruption of the brood cycles occurred in 50% of the carbaryl-treated colonies and in 100% of those exposed to acephate. This seems a little incongruous, since living queens were observed in most of the colonies at the first post-spray inspection. Johansen (personal communication) has hypothesized that either the reduction in number of hive bees, or an alteration of their behavior due to the chemicals, may diminish the supply of royal jelly fed to the queen, thus depriving her of protein needed for egg production.

There seems to be no completely satisfactory explanation for the severity of acephate effects that occurred in the study. Cold weather during the acephate applications could account for increasing the residual hazard to bees from several hours to several days (Johansen, 1976a). A sizable conversion of acephate to methamidophos occurred between the time tank samples and 0-day duff and foliage samples were taken for chemical analysis (Roberts, 1977). In the 0-day pollen sample taken from LAC, 87% of detected residues were methamidophos (R.R. Roberts, pers. comm.). Both of these items help explain the unexpectedly severe killing of bees. A third explanation relates to changes during the development of acephate from initial laboratory samples, through pilot experimental batches, to final commercial production. Increasing quality control and purity of the final product appear to be associated with increasing effectiveness against target pest insects as well as toxicity to bees.

Wild Bee Studies

Sightings of bees are shown for 8 genera of plants in Tables 5-12. In some cases, 25 square yards could not be observed, and the figures are extrapolated from sightings totalling at least 10 square yards.

LC2. Although there are no pre-spray data for Trifolium at GC2, post-spray data indicate a similar effect occurred on that plot. On both carbaryl plots, Osmia numbers on clover had returned to normal within 2 weeks. Bombus foragers on Symphoricarpos were badly reduced at GC2 and did not recover for about a month.

Effects from acephate are detectable in several cases. On Mertensia at JC, Osmia and possibly Bombus were reduced without sign of recovery within 17 days of post-spray sampling. At LAC on Symphoricarpos, Bombus appear to have been reduced for about a month, though the data base was small. On Phacelia at JC, Bombus populations were again sizable 17 days after spray, though megachilid populations did not recover until 29 days after application. At LAC there probably was a 3-5 day depression of Bombus foragers on Solidago.

On diflubenzuron-treated plots there was only one case where a forager depression may be indicated. This is at BC on Symphoricarpos, where Bombus numbers were low for a month following the spray. However, lack of blooms during the pre-spray period prohibits verification of the effect.

On one check plot, WC, there is evidence of a reduction in foragers after spray. On Taraxacum honey bee numbers were decreased somewhat.

Obviously, wild bee observations are not as dependable an index of insecticide effects as honey bee data. In some cases, ostensible reduction of foragers may be attributable to natural population fluctuations or to the abandonment of the observed plant in favor of a more attractive flower elsewhere. Use of wild bee sightings should thus be of a supportive nature. However, depression of foraging activity was observed much more frequently on the plots where killing of honey bees was severe than on the diflubenzuron or check plots.

It is important to note that there is a succession of bees emerging through the summer, and that a temporary disruption of populations will not necessarily

be maintained through the season. Finnigan (1968), working at similar elevations in northern Idaho, found 8 species of Osmia occurring in an overlapping sequence from mid-June through mid-August. Individual species also were present for months at a time. Though species of Osmia were not determined in this study, there was an obvious, similar succession. Likewise, working with essentially the same Bombus species as were encountered in Oregon, Finnigan found most species occurring from late May into early September. This is precisely what was observed in our study.

The most prevalent Bombus sp. in each plot often varied between seasons and successful Bombus nests were apparently rare in the plots. Therefore, many of the foraging bumble bees observed may have moved up from lower elevations during favorable days, and new queens may move down to lower elevations in search of hibernating sites during late summer and fall. This would also tend to reduce the effects of single applications of sprays at higher elevations.

Malaise Trapping

Malaise trap data were not consistent enough to use as an indicator of pesticide impact. Fluctuations from one day to another and from one plot to another followed no discernible pattern. Therefore, it is only appropriate to use these data to show which taxa occurred in the study areas. A plot-by-plot summary of the bees caught in the Malaise-type trap over the two seasons is given in Table 13. Bees netted or seen on the plots, but not trapped, are also represented,

Bees occurring in abundance in the Malaise traps are not necessarily the most important forest pollinators, nor the most commonly sighted bees. Halictus especially, and Andrena, to some extent were trapped in numbers disproportionate to what was observed in the field. This is probably due in part to Halictus' greater propensity to use the flyways in which the traps were set up (W. J. Turner, personal communication). Part of the explanation undoubtedly lies in what plant

species were observed for foragers. While Osmia and Bombus visit the more abundant species, Halictus may be visiting flowers which are more scattered and less likely to grow in clumps that lend themselves to sightings. Note that 20 genera of bees were collected or observed on the plots. However, of these Bombus, Osmia add possibly Halictus are major pollinators of the forest understory and meadow plants (e. g. Finnigan, 1968).

Nesting Studies

Sizes of Bombus nests excavated appear in Table 14. Obviously this is a small data base, but the results do show that a single Bombus bifarius nearcticus colony was at least as successful on diflubenzuron-treated BC as a colony of the same species was on GC2 in 1975.

In Table 15 are the numbers of Osmia that nested in the trap boxes in 1976. Probably no conclusion can be safely drawn from these data, unless it is that as many late nesters were found in treated plots as in check plots. This indicates again that the succession of bee species during a season will overshadow brief absences of pollinators created by short-term spray programs.

Flowering Plant Studies

In Table 16 are the results of the study to determine plants' dependence on insects for pollination. These indicate that at least 16 of 19 genera studied produce seeds more successfully with insect pollination, and 8 of these are completely dependent upon insects. Several of these plants, or related species, have been studied before with similar results. Commercially grown Allium requires insect pollination (McGregor, 1976). Macior's (1974) results on Aconitum columbianum, Castilleja, Delphinium, Iris, Lupinus, Mertensia and Thermopsis all are in close accord with those of this study. Macior found Phacelia sericea to be moderately self-fruitful, though benefitted by insects. Phacelia hastata is apparently more dependent upon insects. Manning (1943) includes Symphoricarpos among the plants

he states are benefitted by cross-pollination.

Slightly surprising was the discovery that Veratrum californicum was more fruitful when open-pollinated. Atkins (1975) lists this species among those which are poisonous, or suspected as such, to bees. Indeed, very few bees were ever observed near these plants. E. J. Davis (personal communication) netted large numbers of syrphids and anthomyids on these flowers, so Veratrumis most likely a "fly flower."

Results of the germination tests (Table 17) are scant because of difficulties encountered in trying to germinate seeds, and because of failure to collect enough seed from certain species to conduct statistically meaningful tests. In the two species studied, insect pollination did improve germination percentage. This emphasizes the need for more studies of this sort. Production of non-viable seed may still benefit wildlife, but it is of no use in plant reproduction.

Free (1970) correctly contends that experiments which attempt to determine the effe f insect pollination by comparing only seed yield of caged plants with seed yield of uncaged plants are unsatisfactory because they do not recognize the effect of the cage itself. There should ideally be 3 treatments in such experiments: 1) caged with bees; 2) caged without bees; and 3) open-pollinated. Clearly, this design was impractical under the circumstances of this study. Temperature and relative humidity effects of the various cages appear in Table 18. In all 3 cage sizes, temperature was slightly higher than outside the but not significantly cage. In one of 3 cage sizes, relative humidity was significantly reduced. Other factors that might be affected by screening, such as light intensity and wind speed, were not measured. It is not clear what effect the small temperature and relative humidity changes might have on the plants studied. No symptoms of damage (other than low fruit production) were readily apparent in any of the caged species. Several authors (Free and Spencer-Booth, 1963; Rubis et al., 1966) have found yield of commercially grown crops adversely affected by caging.

Percentages of fruit set by plants in treated vs. non-treated plots appear in Table 19. Fruit production by Mertensia at JC was much lower than at WC, while Symphoricarpos and Cynoglossum fruit production at GC2 and LAC was normal. It is noteworthy that Mertensia is rarely visited by honey bees, while Cynoglossum and Symphoricarpos are very attractive to honey bees. Reduction of Osmia and Bombus at JC would thus explain Mertensia's low fruit production , while honey bee foraging maintained the pollination of Cynoglossum and Symphoricarpos despite depression of the numbers of wild bees in those plots.

CONCLUSIONS

1. Carbaryl (Sevin-4-oil) at 2 lb ai/acre killed large numbers of honey bees, 11,850 - 19,942/colony (check-corrected range) during the first week after application. It disrupted the brood cycle and caused supercedure of the queen in 2 colonies, and left the other 2 very weak. Three of the 4 colonies were dead by January 77. Carbaryl also killed honey bees in the 4 closest check plot colonies (375- 5,936/colony during the first week).

2. Surprisingly, acephate at both one and 2 lb ai/acre was more detrimental than carbaryl to honey bee colonies. Obviously, many foraging workers succumbed to this faster-acting chemical in the field, since only 2100- 3387/colony were obtained in dead bee traps on the hives during the first week. Brood cycles of the 4 colonies were permanently broken and all were technically dead within 45-48 days after treatment (small amounts of drone brood produced by laying workers were present in 2 of the colonies). One colony in the nearest check plot suffered some loss due to acephate, but its death by January 77 may not have been a direct result of the treatment.

3. Diflubenzuron at both 2 and 4 oz ai/acre had no effect on adult honey bee death rates or brood production.

4. Depressions in numbers of foraging wild bees were apparent in all plots treated with carbaryl or acephate. In contrast, reductions in foraging activity were rare in check or diflubenzuron-treated plots.
5. At least 16 of 19 plants tested showed a benefit from insect pollination. Seeds of 2 species germinated more successfully when insect-pollinated.
6. Fruit production of Mertensia was severely reduced on an acephate-treated plot. Other species studied may have set normal numbers of fruit due to the introduction of honey bees for the study.
7. All other factors being equal in a cost-benefit analysis, the results of this study encourage the use of diflubenzuron if control measures for Douglas-fir tussock moth are deemed necessary in the future.
8. A single application of acephate or carbaryl in Pacific Northwest forests at 4–6,000 ft elevation is unlikely to cause either a severe or long-term impact because of reduction in insect pollination. Bumble bees, the most prevalent and important pollinators, apparently move up from lower elevations during the season. A succession of earlier and later-emerging species of both Bombus and Osmia occurs through the season and a considerable variation in intra-specific timing also occurs.

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APPENDIX A

TABLES

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Table 2. Plot allocations, dates and weather conditions of treatments applied to selected plots in Wallowa-Whitman National Forest, June 76.

Date	Plot	Treatment	Temp. C	Wind Speed
23 June 76	LAC	Acephate 1 lb ai/acre	2.8	3-4 mph
24 June 76	JC	Acephate 2 lb ai/acre	7.3	2-3 mph
26 June 76	VC	Diflubenzuron 4 oz ai/acre	-1.1	1-2 mph
26 June 76	BC	Diflubenzuron 2 oz ai/acre	10.1	3-4 mph
27 June 76	GC2	Carbaryl 2 lb ai/acre	2.8	2-3 mph
27 June 76	LC2	Carbaryl 2 lb ai/acre	10.2	2-3 mph

Table 3. Dead bees trapped ~~per day~~ per day from honey bee colonies, for indicated time periods.

Colony	Treatment	1975 per day	Pre-spray 1976	Spray date	Day 2	3	4	5	6	7	8	9	10	11
LC1-A	Check	24	45	843	1364	1233	920	515	-	1331	-	49	380	85
LC1-B	"	36	30	1095	2580	1265	656	276	-	571	-	38	74	61
GC1-A	"	37	38	227	62	112	94	37	-	71	-	9	-	6
GC1-B	"	68	28	293	172	175	153	155	-	771	-	830	-	210
WC-A	"	45	16	42	16	91	64	66	47	56	-	160	78	60
WC-B	"	32	42	76	60	407	82	30	151	124	-	175	106	104
BC-A	Diflubenzuron 2 oz	44	57	64	108	60	43	62	65	-	74	-	32	3
BC-B	"	39	43	51	105	49	53	59	31	-	68	-	46	24
VC-B	Diflubenzuron 4 oz.	27	41	25	75	27	84	123	73	-	67	-	53	44
VC-A	"	29	33	26	55	16	18	55	56	-	48	-	51	34
GC2-A	Carbaryl 2 lb	28	42	6390	5635	2795	1105	1012	-	2160	-	1635	-	1137
GC2-B	"	36	27	7730	2905	1812	672	890	-	1364	-	1169	-	860
LC2-A	"	25	52	2085	2580	1740	1105	742	-	3910	-	2160	328	-
LC2-B	"	33	30	11025	3910	1812	1298	713	-	1364	-	1105	713	-
JC-A	Acephate 2 lb	34	36	1101	327	627	688	452	268	121	-	328	115	90
JC-B	"	30	49	1163	376	457	91	125	122	60	-	200	124	40
LAC-A	Acephate 1 lb	35	23	1650	425	225	367	434	243	155	133	-	543	225
LAC-B	"	32	36	1670	316	205	571	543	138	160	81	-	276	106

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Table 4. Brood measurement and colony condition 1975 and 1976.

Colony	Treatment	Sq in brood[1] Aug 1975	Sq in brood 10-12 days post-spray	Sq in brood 45-48 days post-spray	Colony condition Oct 1976	Colony condition, Jan 77	Remarks
LC1-A	Check	750	1216	1065	OK	OK	Both colonies contaminated by LC2 treatment
LC1-B		600	1109	1020	OK	OK	
GC1-A	Check	1200	10	1190	OK	OK	Colony A very weak at beginning of 1976 season
GC1-B		1200	1441	1502	OK	OK	
WC-A	Check	900	637	760	Weak	Weak	Colony B contaminated by JC treatment. Brood all
WC-B		900	1145	0	Weak	Dead	old at 10-day inspection, 1976.
BC-A	Diflubenzuron 2 oz	750	1247	1480	OK	OK	No effect from diflubenzuron. Queen of colony B
BC-B		600	1431	1300	Below avg	Dead	apparently lost about time of 45-day inspection, 1976
VC-A	Diflubenzuron 4 oz	1050	1142	782	OK	OK	No effect from diflubenzuron
VC-B		600	1130	1177	OK	OK	
GC2-A	Carbaryl 2 lb	1200	700	885	Weak	Dead	Heavy kill from carbaryl, brood rearing continued but
GC2-B		1200	415	565	Weak	Weak	erratic. Colony A winter-killed.
LC2-A	Carbaryl 2 lb	600	678	0	Dead	Dead	Brood cycle broken within 1-2 days. Colony B lost
LC2-B		200	357	40[2]	Dead	Dead	queen, 1975.
JC-A	Acephate 2 lb	750	56	50[2]	Weak	Dead	Brood cycle broken within 2-3 days.
JC-B		900	81	0	Dead	Dead	
LAC-A	Acephate 1 lb	900	57	15[2]	Weak	Dead	Brood cycle broken within 2-3 days.
LAC-B		750	85	0	Dead	Dead	

[1] Estimated on basis of 150 sq in/frame.
[2] Drone brood produced by laying workers.

Table 5. Bees observed per 25 sq yd observation on Trifolium sp., 1976.

Plot	Bee	Number of days pre or post-spray -7	-3	0	1	2	4	5	9	10	11	13	14	15	16	28
LC2	Osmia	-	16.7	32.1	4.2	-	1.7	-	-	4.9	20.0	32.5	35.2	-	13.0	-
BC	Osmia	11.0	-	-	25.0	6.3	-	32.1	-	-	-	-	-	27.3	15.6	-
LC1	Osmia	--	-	-	-	-	-	-	23.3	29.2	-	8.3	45.5	-	-	36.3
GC1	Osmia	-	-	-	-	-	7.1	-	-	-	-	18.0	18.3	-	7.0	-
"	Apis	-	-	-	-	-	25.0	-	-	-	-	6.0	5.0	-	19.0	-
GC2	Osmia	-	-	-	-	-	0	-	-	-	-	25.0	58.3	-	37.5	-
"	Apis	-	-	-	-	-	6.3	-	-	-	-	12.5	16.7	-	0	-

Table 6. Bees observed per 25 sq yd observation on Mertensia paniculata, 1976.

Plot	Bee	Number of days pre or post-spray -12	-6	-2	0	3	4	9	11	12	13	15	17
JC	Osmia	-	4.0	5.0	2.0	0	0	1.0	0	0	-	0	-
"	Bombus	-	4.0	3.0	6.0	12.0	8.0	3.0	5.0	1.0	-	0	-
VC	Osmia	21.0	6.0	-	11.0	10.0	-	-	-	-	-	-	32.0
"	Bombus	1.0	6.0	-	5.0	0	-	-	-	-	-	-	7.0
WC	Osmia	-	-	-	-	-	-	-	-	-	27.8	21.7	-
"	Bombus	-	-	-	-	-	-	-	-	-	0	1.7	-

Table 7. Bees observed per 25 sq yd observation on Cynoglossum officinale, 1976.

Plot	Bee	Number of days pre or post-spray -16	-13	-7	-3	-2	-1	0	1	2	3	4	5	10
GC2	Bombus	11.0	9.0	3.0	0	-	1.0	2.5	1.3	1.0	0	0.8	-	-
"	Apis	0	0	20.0	28.1	-	20.0	40.0	26.4	11.0	16.0	39.4	-	-
GC1	Bombus	-	7.5	7.0	12.5	-	-	-	0	8.3	-	-	-	-
"	Apis	-	0	7.0	18.8	-	-	-	25.0	3.3	-	-	-	-
VC	Bombus	-	-	-	-	0	-	25.0	50.0	43.8	23.7	14.5	25.0	11.7
"	Apis	-	-	-	-	6.3	-	1.9	0	6.3	5.3	7.9	0	15.0

Table 8. Bees observed per 25 sq yd observation on Vicia sp., 1976.

Plot	Bee	Number of days pre or post-spray -1	0	3	4	5	10	11	14	15	17
BC	Osmia	2.0	4.0	16.0	25.0	25.0	23.8	25.0	32.5	55.0	75.0
"	Bombus	6.0	6.0	0	0	3.1	0	1.4	0	0	0
"	Anthophoridae	2.0	3.0	2.0	4.0	6.3	7.5	1.4	0	5.0	0

Table 9. Bees observed per 25 sq yd observation on Taraxacum sp., 1976.

		Number of days pre or post-spray														
Plot	Bee	-16	-15	-8	-6	-3	-1	0	1	2	3	4	5	6	9	11
WC	Halictus	-	-	-	7.5	-	1.7	0	-	-	0	1.0	-	-	2.0	0
"	Osmia	-	-	-	0	-	0	1.0	-	-	2.0	0	-	-	2.0	3.3
"	Apis	-	-	-	10.0	-	11.7	9.0	-	-	7.0	3.0	-	-	3.0	5.0
JC	Halictus	-	5.0	-	-	-	-	-	-	0	-	-	0	0	-	-
"	Osmia	-	0	-	-	-	-	-	-	0	-	-	2.5	0	-	-
"	Bombus	-	0	-	-	-	-	-	-	10.0	-	-	0	0	-	-
LC1	Apoidea	8.0	-	14.0	-	16.7	-	16.7	-	-	-	15.0	-	-	-	-

Table 10. Bees observed per 25 sq yd observation on Phacelia hastata, 1976.

		Number of days post-spray							
Plot	Bee	14	16	17	22	28	29	32	35
JC	Anthidium	-	-	0	0	-	4.0	6.3	0
"	Osmia	-	-	1.0	0	-	9.0	3.1	0
"	Bombus	-	-	9.0	14.0	-	17.0	10.9	12.0
WC	Anthidium	-	-	0	3.8	-	-	0	13.6
"	Osmia	-	-	12.5	16.2	-	-	0	8.0
"	Bombus	-	-	0	11.3	-	-	7.0	20.5
LC1	Megachilidae	25.0	61.7	-	-	33.3	-	-	-
"	Anthophoridae	9.1	8.3	-	-	0	-	-	-

Table 11. Bees observed per 25 sq yd observation on Solidago sp., 1976.

Plot	Bee	Number of days post-spray 0	3	6	16
LAC	Megachilidae	20.5	12.5	21.0	0
"	Bombus	2.3	3.1	21.0	15.0

Table 12. Bees observed per 25 sq yd observation on Symphoricarpos albus, 1976.

Plot	Bee	Number of days pre or post-spray																	
		-1	7	8	9	10	11	13	14	15	16	17	18	23	28	29	30	31	33
GC2	Bombus	16.7	0	-	0	0	0	0	0	-	0	-	-	-	2.0	-	2.0	-	-
"	Apis	8.3	11.0	-	10.0	-	-	13.0	25.0	-	33.0	-	-	-	13.0	-	24.0	-	-
GC1	Bombus	-	-	-	-	-	-	-	-	-	-	-	-	-	5.0	-	-	-	-
"	Apis	-	-	-	-	-	-	-	-	-	-	-	-	-	13.0	-	-	-	-
VC	Bombus	-	-	-	-	-	-	-	10.0	-	-	-	-	-	-	13.0	-	9.0	-
"	Apis	-	-	-	-	-	-	-	10.0	-	-	-	-	-	-	12.0	-	29.0	-
BC	Bombus	-	-	6.0	-	1.0	4.0	-	2.0	2.0	-	2.0	-	-	-	2.0	-	14.0	-
"	Apis	-	-	15.0	-	40.0	6.0	-	31.0	12.0	-	12.0	-	-	-	28.0	-	8.0	-
LC2	Bombus	-	-	-	-	-	-	-	-	-	-	-	-	-	5.0	-	-	-	-
"	Apis	-	-	-	-	-	-	-	-	-	-	-	-	-	12.0	-	-	-	-
LAC	Bombus	-	-	-	-	-	-	-	-	-	-	-	0	0	-	-	17.0	25.0	-
"	Apis	-	-	-	-	-	-	-	-	-	-	-	0	0	-	-	5.0	2.0	

CONTINUED →

Table 12. (Continued)

Plot	Bee	Number of days post-spray							
		34	35	36	40	41	47	55	56
GC2	Bombus	12.0	-	-	0	-	-	-	-
"	Apis	9.0	-	-	10.0	-	-	-	-
GC1	Bombus	-	-	-	-	-	-	-	-
"	Apis	-	-	-	-	-	-	-	-
VC	Bombus	-	10.0	-	-	10.0	-	-	9.0
"	Apis	-	18.0	-	-	16.0	-	-	17.0
BC	Bombus	-	-	-	-	12.0	-	-	5.0
"	Apis	-	-	-	-	18.0	-	-	15.0
LC2	Bombus	-	-	-	-	-	-	0	-
"	Apis	-	-	-	-	-	-	0	-
LAC	Bombus	-	-	32.0	-	-	12.0	-	-
"	Apis	-	-	4.0	-	-	2.0	-	-

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Table 13. Numbers of bees caught in Malaise-type traps during summers of 1975 and 1976.

Bee	Plot								
	LAC	WC	JC	LC1	LC2	BC	VC	GC1	GC2
Colletes	11	N[1]	6	0	0	3	N	2	3
Hylaeus[2]	N	5	2	6	7	8	N	14	222
Halictus	69	32	12	54	25	65	25	169	238
Sphecodes[2]	9	0	0	N	1	7	2	3	2
Dufourea	0	0	0	0	0	3	0	0	0
Andrena	27	11	5	2	N	1	10	N	6
Anthidium	0	0	N	N	N	0	0	N	7
Dianthidium	0	0	0	0	0	0	0	0	1
Megachile	1	N	N	N	N	N	N	1	2
Coelioxys[2]	0	0	1	0	0	0	0	0	0
Hoplitis	0	0	0	1	0	1	0	0	2
Osmia	15	7	7	13	4	17	2	7	23
Melissodes	N	0	N	0	0	0	0	0	0
Tetralonia	0	0	0	0	0	0	0	0	2
Anthophora	0	0	0	N	N	1	0	3	1
Emphoropsis	0	0	0	N	N	N	0	0	0
Ceratina	0	0	0	0	0	1	N	N	1
Apis mellifera L.	1	9	2	3	3	4	11	9	15
Bombus appositus Cresson	1	1	N	0	N	0	0	0	0
B. bifarius nearcticus Handlirsch	5	8	9	N	4	5	2	5	3
B. californicus consanguineus Handlirsch	1	0	0	0	0	0	0	0	0
B. centralis Cresson	N	N	N	N	1	3	N	1	2
B. fervidus (Fabricius)	0	0	0	N	N	0	0	0	0
B. flavifrons Cresson	N	1	0	0	0	1	2	1	N

Table 13. (Continued)

Bee	Plot								
	LAC	WC	JC	LC1	LC2	BC	VC	GC1	GC2
B. mixtus Cresson	N	2	1	N	N	1	1	4	N
B. occidentalis Greene	3	15	1	10	6	13	18	10	10
B. vagans F. Smith	1	0	1	0	0	0	1	0	1
Psithyrus[2]	1	N	N	N	1	2	N	3	3

1 The symbol "N" indicates the bee was netted or seen on the plot, but was not caught in the Malaise-type trap.

2 Absence of pollen-gathering scopae diminishes the importance of this bee as a pollinator.

Table 14. Numbers of workers and cells in excavated Bombus colonies, Aug 75 and 76.

Species	Plot	Year	Treatment	# workers	# cells
B. bifarius nearcticus	GC1	1975	None	27	144
B. bifarius nearcticus	BC	1976	Diflubenzuron 2 oz	36	195
B. occidentalis	LC1	1975	None	20	93
B. occidentalis	JC	1975	None	54	302

Table 15. Numbers of Osmia trap-nested, 1976. All nesting occurred after mid-July.

Plot	Treatment	# Osmia
LC1	Check	12
GC1	Check	0
WC	Check	0
BC	Diflubenzuron 2 oz	1
VC	Diflubenzuron 4 oz	1
GC2	Carbaryl 2 lb	9
LC2	Carbaryl 2.1b	3
JC	Acepnate 2 lb	0
LAC	Acephate 1 lb	18

Table 16. Fruit production on selected forest plants.

	Under exclosures			Open-pollinated	
	Total flowers	Total seed-bearing fruit	Percent	Total flowers	Total seed-bearing fruit
Aconitum columbianum	111	0	0	199	185
Allium sp.	726	1	1	734	691
Aquilegia sp.	154	79	51	172	123
Brodiaea douglasii	22	16	73	41	38
Castilleja miniata	52	0	0	60	36
Cynoglossum officinale	425	2	[illegible]	507	42
Delphinium sp.	183	0	0	195	90
Iris sp.	20	0	0	20	19
Lupinus sp.	536	0	0	480	124
Mertensia paniculata	1640	0	0	1584	697
Oxytropis campestris	318	0	0	280	186
Phacelia hastata	445	83	19	409	342
Potentilla sp.	246	246	100	205	203
Sedum sp.	69	58	84	72	67
Senecio triangularis	360	320	88	365	365
Solidago sp.	737	551	75	614	562
Symphoricarpos albus	324	85	26	376	151
Thermopsis montana	42	0	0	68	31
Veratrum californicum	1238	177	14	1073	858

Table 17. Pooled-t test between numbers of successfully germinating open-pollinated seeds and seeds pollinated under screen.

Plant	Days incubated	$\bar{X}$ germinated[1] Screened	Open-pollinated	SD_p	Pooled-t
Aquilegia sp.	30	0.3	4.8	1.12	11.36**
Potentilla sp.	14	19.0	42.8	8.57	7.85**

1 based on 4 trials of 100 seeds each for both open-pollinated seeds and seeds pollinated under screen.

** Significant at .01 level.

Table 18. Paired-t test between temperatures and relative humidities measured under screen and among nearby plants.

Cage dimensions	$\bar{x}$ Temp F[1] Caged	Open	SD_d	Paired-t	$\bar{x}$ Rel. Hum.[1] Caged	Open	SD_d	paired-t
Cylinder 2' diam x 3'	76.9	74.6	2.16	2.38	44.2	44.9	0.57	2.75
Cylinder 1' diam x 3'	75.8	75.4	0.35	2.53	38.5	38.4	0.50	0.45
2' x 3' x 3'	76.6	75.8	0.76	2.36	39.3	40.6	0.76	3.83*

1 compiled from 5 measurements on different days, both in cages and among nearby plants.
* Significant at .05 level

Table 19. Effect of insecticide treatments on fruit production by insect-pollinated plants.

			TREATED			CHECK			
Species	Plot	Treatment	Total flowers	Total seed-bearing fruit	%	Plot	Total flowers	Total seed-bearing fruit	%
Cynoglossum officinale[1]	GC2	Carbaryl 2 lb	426	310	73	GC1	480	301	63
Mertensia paniculata[1]	JC	Acephate 1 lb	1234	172	14	WC	1306	701	54
Symphoricarpos albus[2]	LAC	Acephate 2 lb	591	272	46	LC1	518	223	44

1 Plants were blooming just as treatments were applied.
2 Plants bloomed 1-2 weeks following treatment.

APPENDIX B

ILLUSTRATIONS

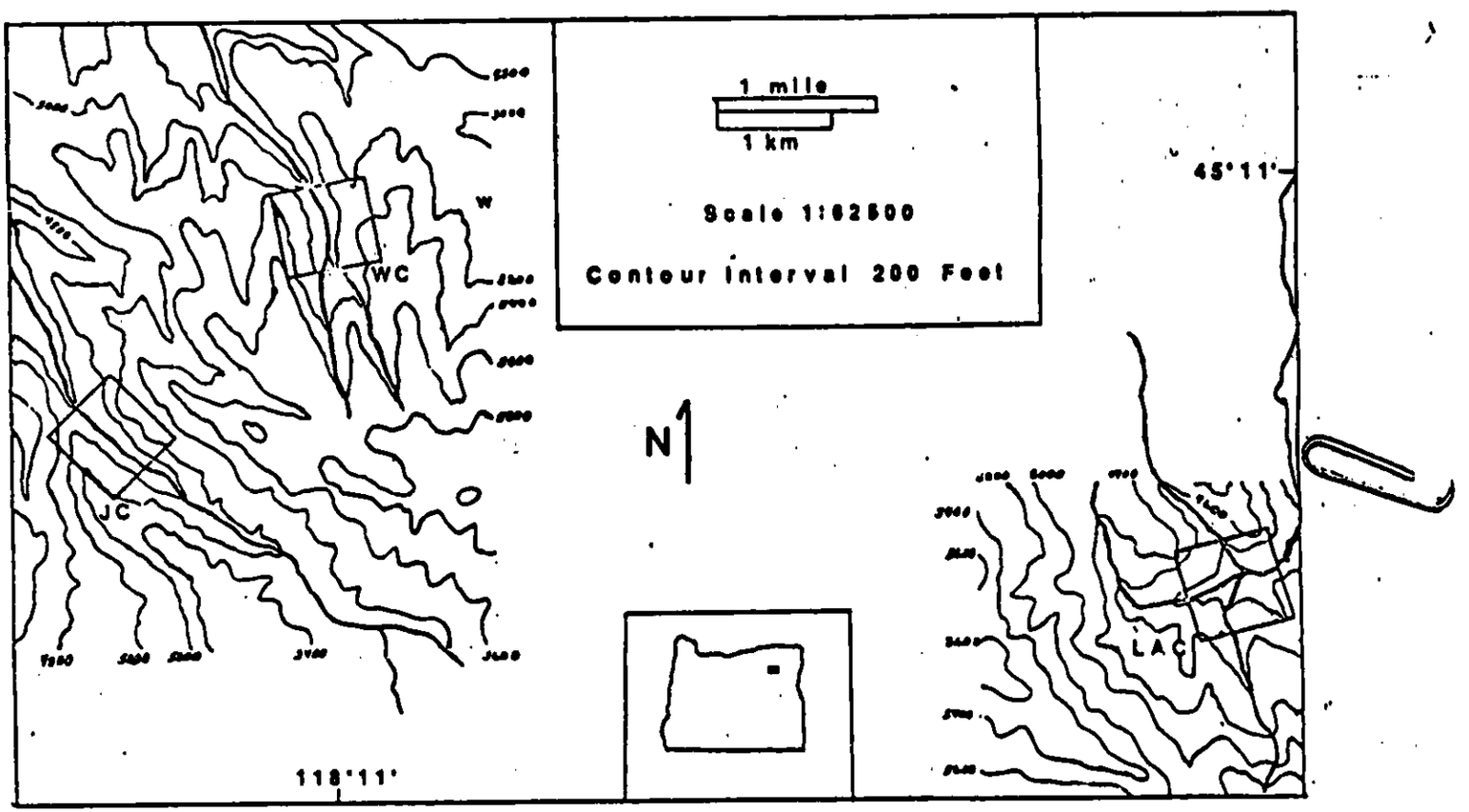

Fig. 1. Location and topography of plots (LAC, WC, JC [illegible]), and location of weather stations (w) in La Grande District of Wallowa-Whitman National Forest.

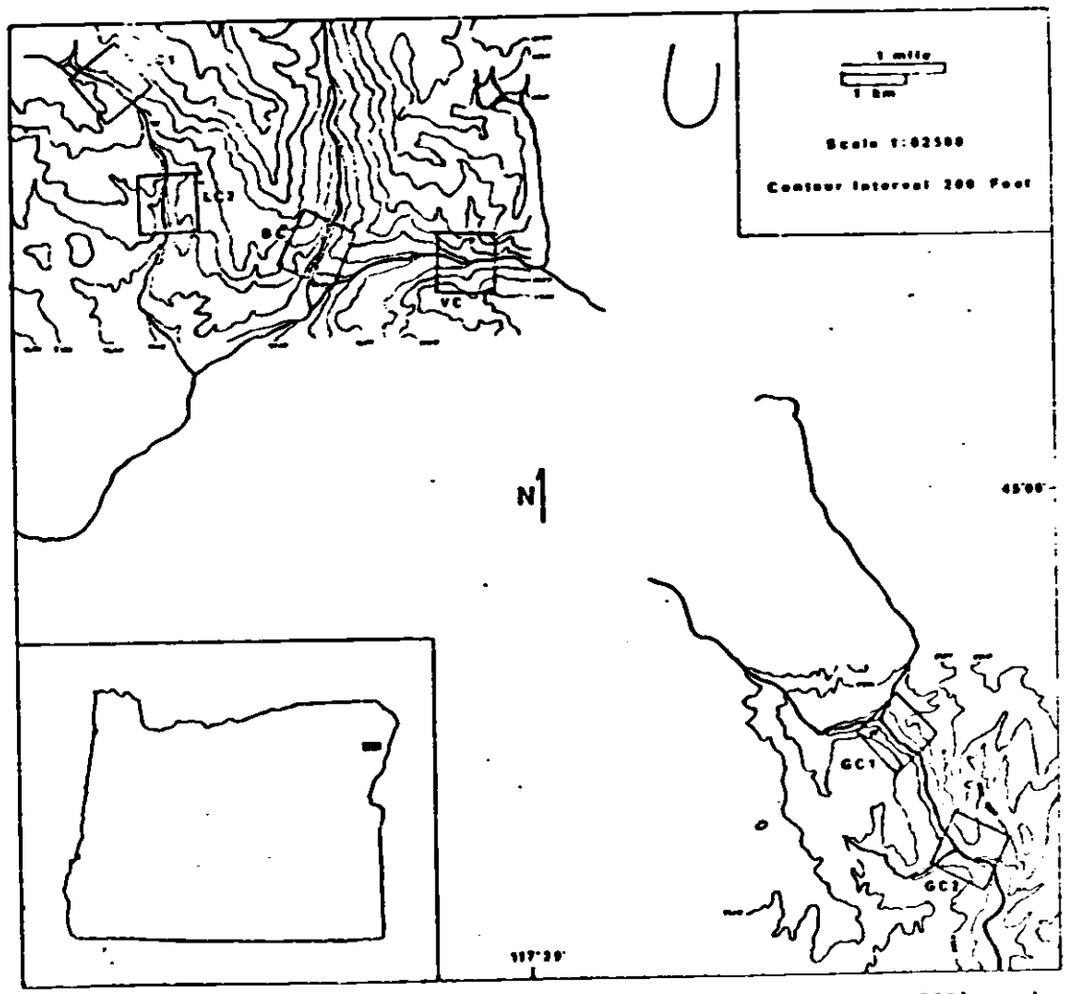

Fig. 2. Location and topography of plots (LC1, LC2, BC, VC, GC1, GC2), and location of weather stations (w) in Union District of Wallowa-Whitman National Forest.

FIGURES 3-7 ARE PHOTOGRAPHS, NOW BEING PROCESSED AT BINDERY.

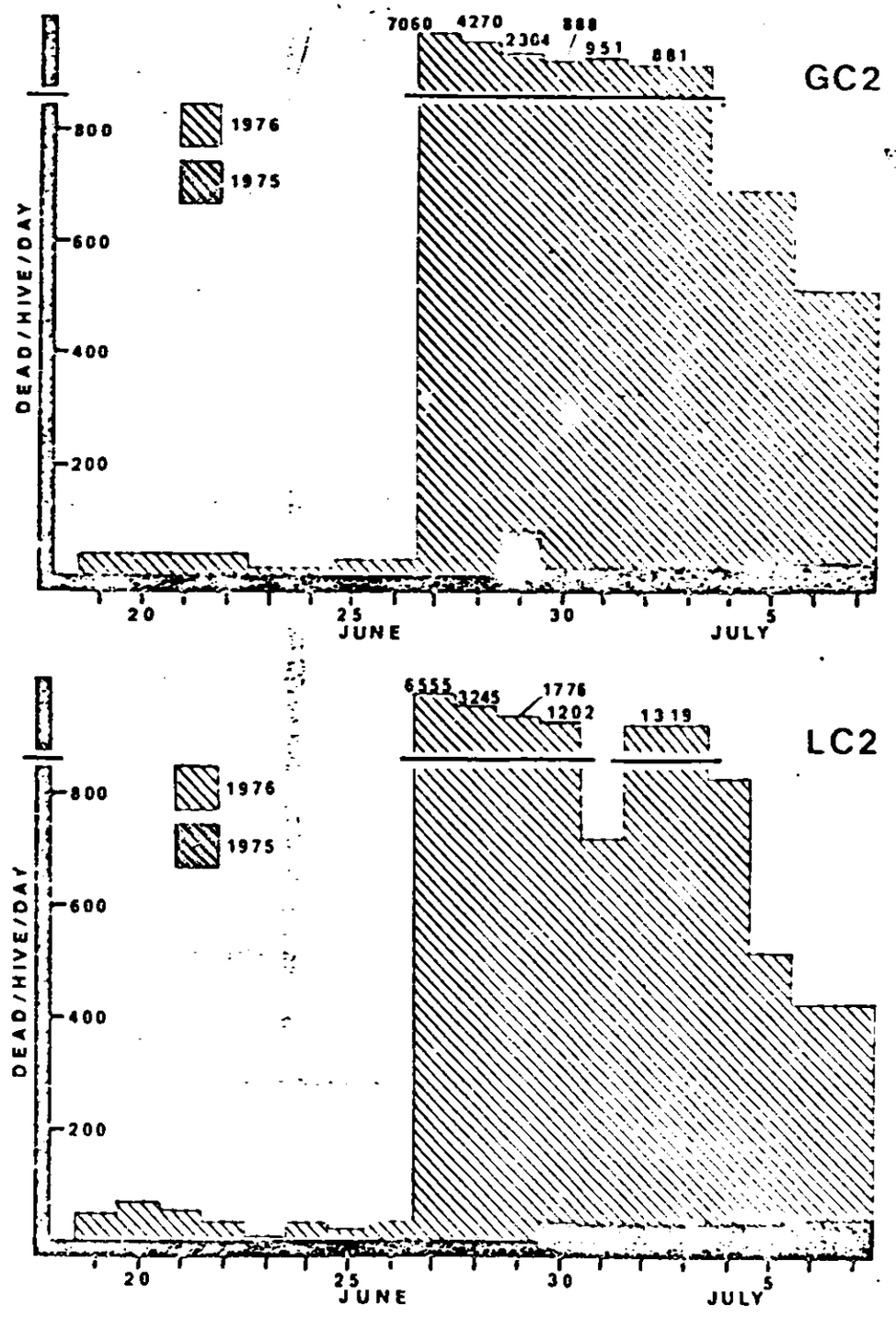

Fig. 8. Comparison of numbers of dead honey bees trapped in 1975 and 1976 on 2 plots(GC2, LC2) treated with carbaryl

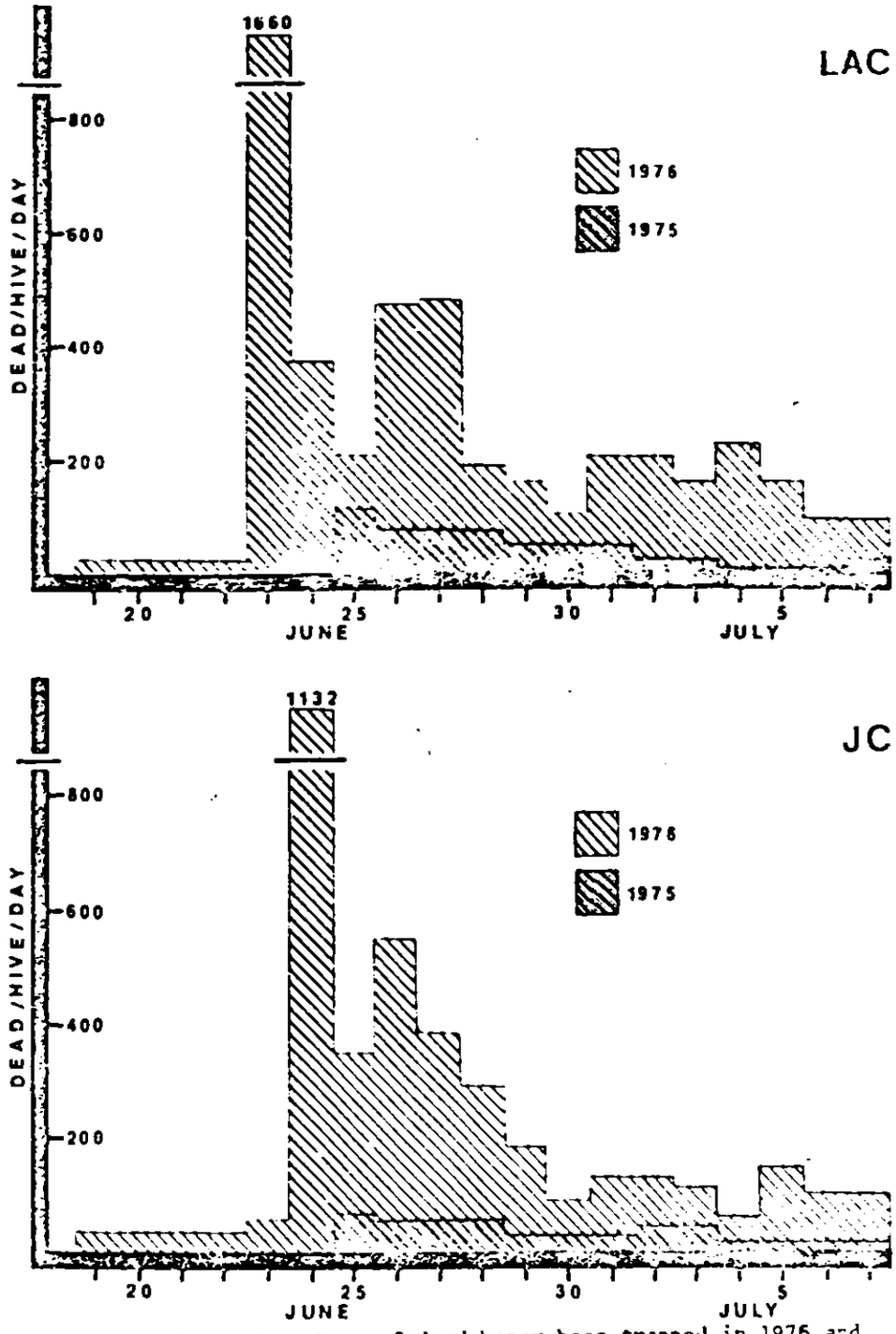

Fig. 9. Comparison of numbers of dead honey bees trapped in 1976 and 1976 on 2 plots (LAC, JC) treated with acephate.

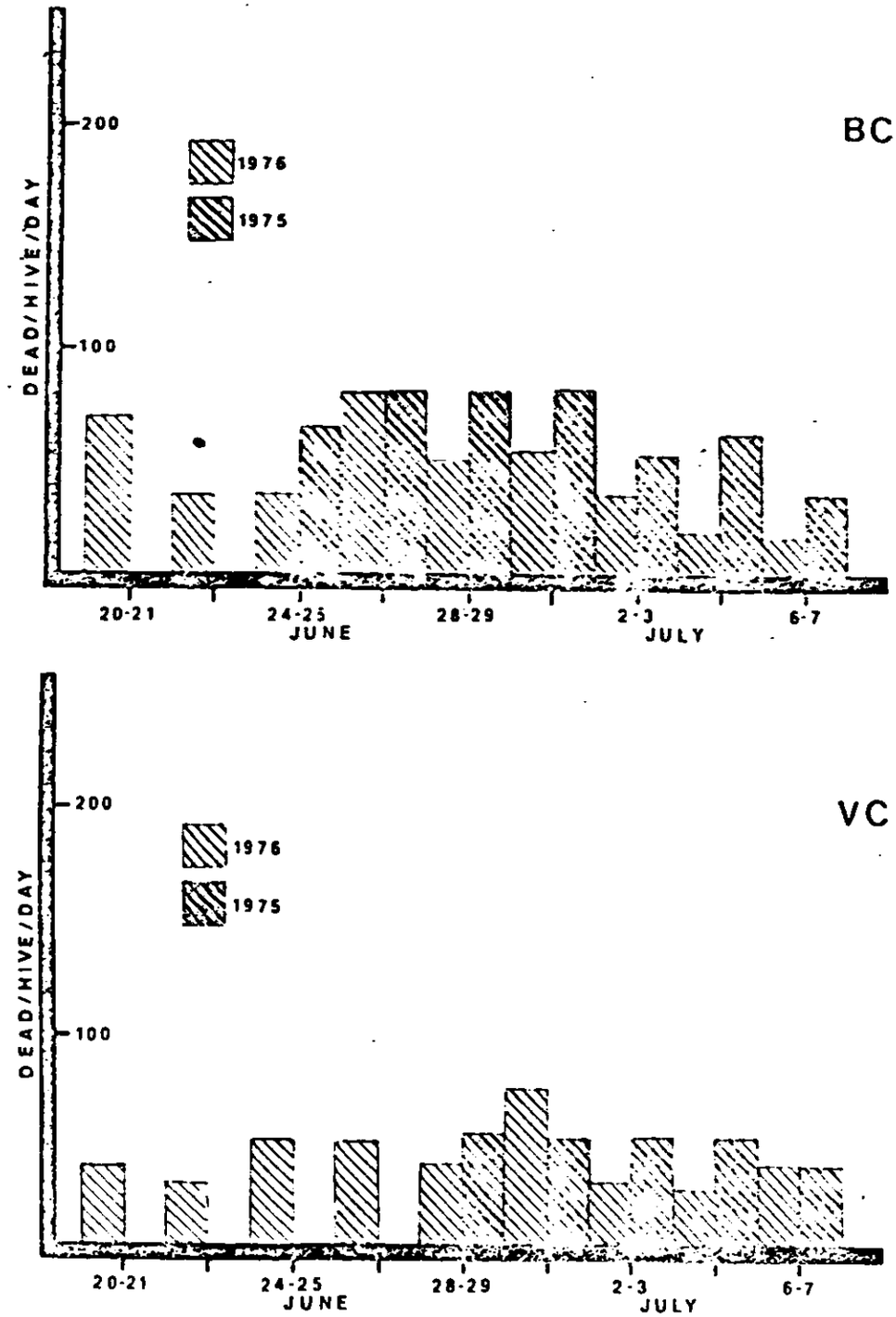

Fig. 10. Comparison of numbers of dead honey bees trapped in 1975 and 1976 on 2 plots treated with diflubenzuron.

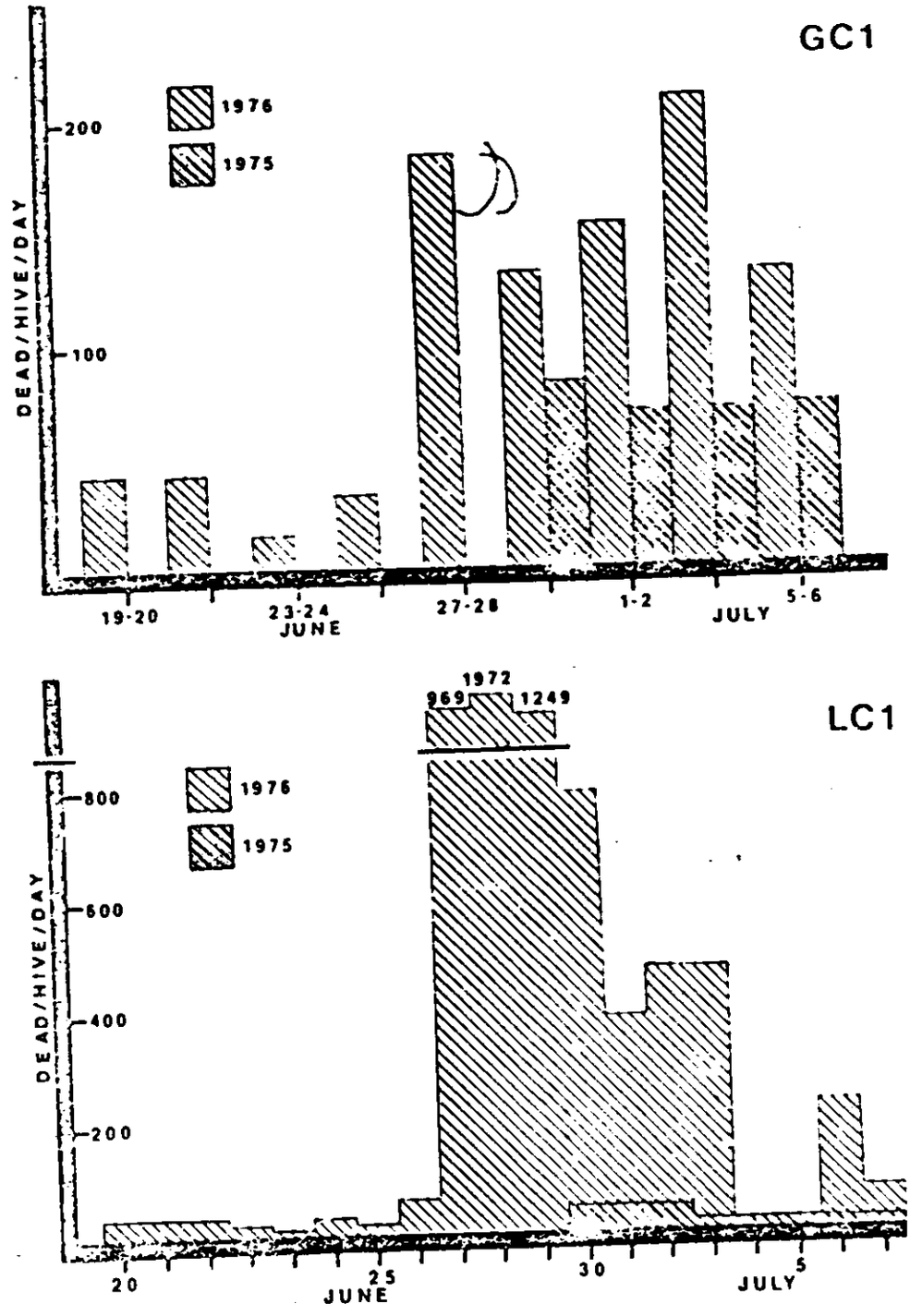

Fig. 11. Comparison of numbers of dead honey bees trapped in 1975 and 1976 on 2 check plots (LC1, GC1) near carbaryl-treated plots.

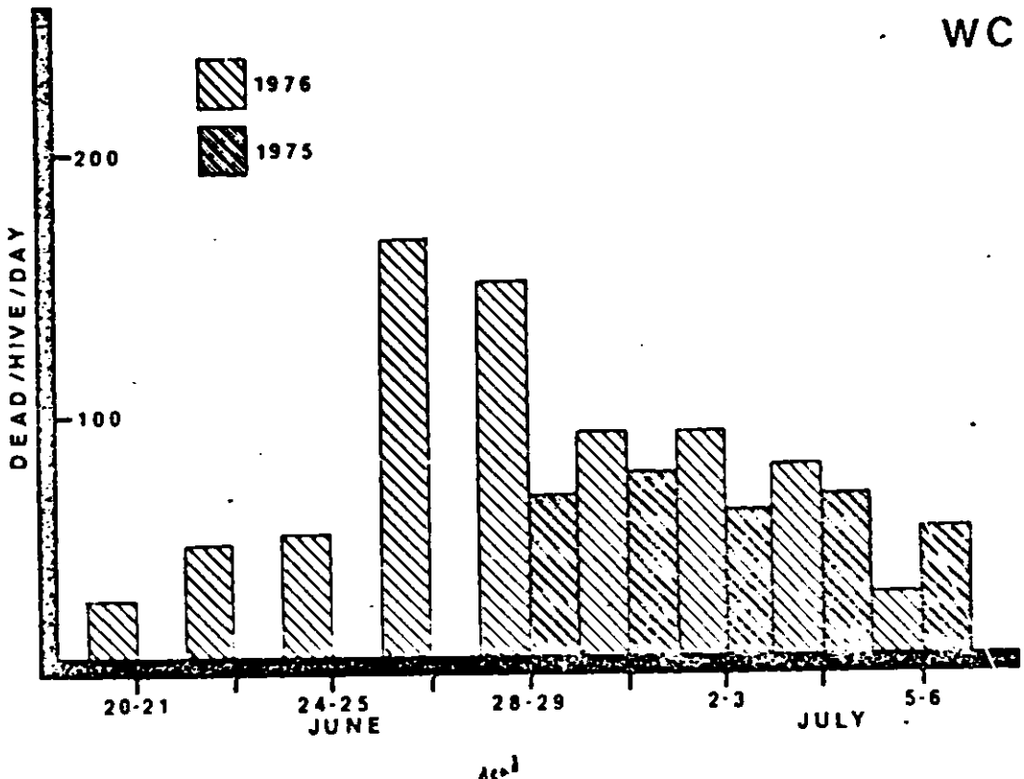

Fig. 12. Comparison of numbers of honey bees trapped in 1975 and 1976 on a check plot (WC).

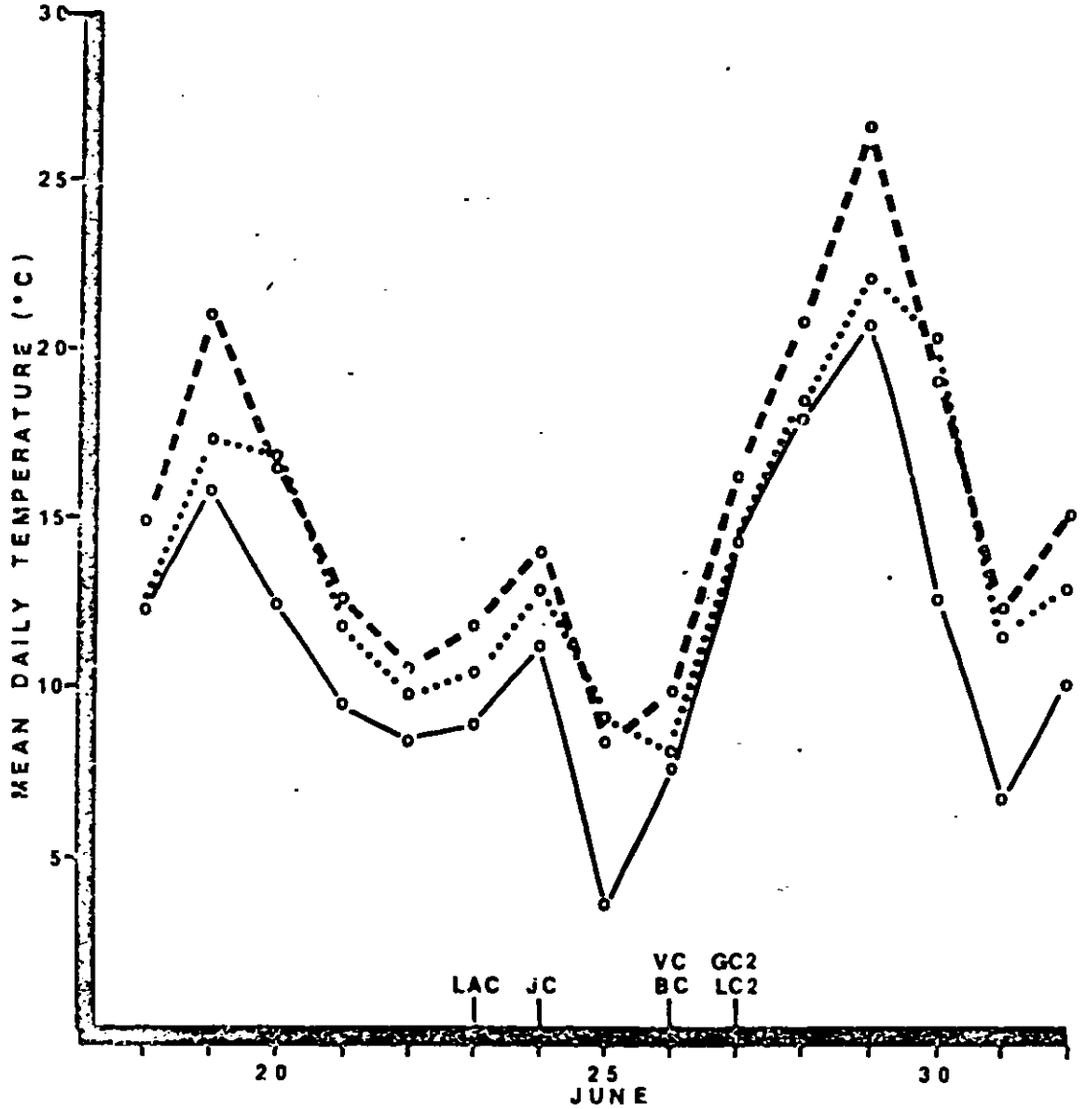

Fig. 13. Mean daily temperatures recorded at 3 weather stations in time period surrounding application dates (solid line, LaGrande District station; dotted line, Goose Ck. station; dashed line, Lick Ck. station). Plot symbols (LAC, JC, VC, BC, GC2, LC2) indicate respective dates of application.